

IN THE MATTER of a  
PCT Application  
in the name of  
Clariant International Ltd.  
filed under **PCT/EP00/07075**  
and  
IN THE MATTER OF its transfer  
for an Application  
for a US Patent

I, Stefan Féaux de Lacroix, Dr. rer.nat., Dipl.Chem., Patentanwalt and European Patent Attorney in Mannheim (F.R.G.), do solemnly and sincerely declare that I am conversant with the English and German languages and am competent in translating thereof, and that the following is, to the best of my knowledge and belief, a true and correct translation of the priority document of German patent application **199 34 798.0 of July 28, 1999**

by Clariant GmbH

for „*Smectic liquid crystal high-contrast control or display device*”

Mannheim, *April 8, 2005*

*Féaux de Lacroix*  
Stefan Féaux de Lacroix  
Patentanwalt



[Translation from German]

FEDERAL REPUBLIC OF GERMANY

(Heraldic emblem)

CERTIFICATE

Clariant GmbH, Frankfurt am Main/DE lodged with the German Patent Office an application for a patent of invention entitled:

***“Smectic liquid crystal high-contrast control or display device”***

on ***July 28, 1999.***

The attached document is a true and accurate copy of the original document of this application for patent.

The German Patent Office has provisionally accorded the application the symbol ***C 09 K, G 02 F*** of the International Patent Classification.

L.S.

Munich, July 20, 2000

The President of the German Patent Office

by proxy

(sgd) Faust

File No.: 199 34 798.0



REC'D 19 SEP 2000

WIPO

Fu

**Prioritätsbescheinigung über die Einreichung  
einer Patentanmeldung**

EP 00/07075

Aktenzeichen: 199 34 798.0

Anmeldetag: 28. Juli 1999

Anmelder/Inhaber: Clariant GmbH, Frankfurt am Main/DE

Bezeichnung: Smektische Flüssigkristallschalt- oder  
Anzeigevorrichtung mit hohem Kontrast

IPC: C 09 K, G 02 F

Die angehefteten Stücke sind eine richtige und genaue Wiedergabe der ursprünglichen Unterlagen dieser Patentanmeldung.

München, den 20. Juli 2000  
Deutsches Patent- und Markenamt

Der Präsident  
Im Auftrag

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**High-contrast smectic liquid-crystal switching or display device**

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5 Displays or electro-optical display devices based on smectic liquid-crystal mixtures as electro-optically active layer are gaining in importance owing to their high response speeds.

10 The use of smectic liquid crystals in electro-optical or fully optical components requires either compounds which form tilted or orthogonal smectic phases and are themselves optically active, or the induction of ferroelectric or electroclinically active smectic phases by doping, with optically active compounds, of compounds which, although forming such smectic phases, are not themselves optically active. The desired phase should also be stable over the broadest possible temperature range 15 to ensure that the display has a broad operating range. In particular, the achievable contrast should be as high as possible over the entire operating range. Liquid-crystal displays may be operated in principle as active- or passive- matrix display.

20 In what is known as active-matrix technology (AMLCD), a nonstructured substrate is usually combined with an active-matrix substrate. An electrically non-linear element, for example a thin-film transistor, is integrated into each pixel of the active-matrix substrate. The non-linear elements can also be diodes, metal-insulator-metal and similar elements, which are advantageously produced by thin-film processes and are described in the relevant literature (see, for example, T. Tsukuda, TFT/LCD: Liquid 25 Crystal Displays Addressed by Thin-Film Transistors, Gordon and Breach 1996, ISBN 2-919875-01-9, and the references cited therein).

Active-matrix LCDs are usually operated with nematic liquid crystals in TN (twisted nematics), ECB (electrically controlled birefringence), VA (vertically aligned), IPS (in-plane switching) or OCB (optically compensated bend) mode. In each case, the active matrix generates an electric field of individual strength on each pixel, 5 producing a change in alignment and thus a change in birefringence, which is in turn optically visible in polarized light. A severe disadvantage of these processes is the poor video capability, i.e. the excessively slow response times of nematic liquid crystals. In particular, nematic LCDs are not capable of displaying sharp moving pictures, as described, for example, in Sueoka et al (K. Sueoka, H. Nakamura and Y. 10 Taira, SID 1997, p. 203-206, ISSN 1083-1312/97/1701-0203).

For this and other reasons, liquid-crystal displays based on the combination of ferroelectric liquid-crystal materials and active-matrix elements have been proposed, for example in WO 97/12355 or in Ferroelectrics 1996, 179, 141-152, or by 15 W.J.A.M. Hartmann (IEEE Trans. Electron. Devices 1989, 36, 9; Pt. 1, pp. 1895-9, and Dissertation, Eindhoven, The Netherlands, 1990), which, however, were never brought to practical maturity owing to a limited temperature range and difficult reproducibility of the smectic texture.

20 While Hartmann utilizes the charge-controlled bistability to display a virtually continuous gray scale, Nito et al. have suggested a monostable FLC geometry (Journal of the SID, 1/2, 1993, pp. 163-169) in which the FLC material is aligned by means of relatively high voltages such that only a single stable position results from 25 which a number of intermediate states are then generated by application of an electric field via a thin-film transistor. These intermediate states correspond to a number of different brightness values (gray shades) when the cell geometry is matched between crossed polarizers.

The disadvantage of the paper by Nito et al. is the occurrence of a streaky texture which limits the contrast and brightness of this cell (see fig. 8 of the abovementioned citation). Furthermore, this method produces switching only in an angle range of up to a maximum of once the tilt angle, which is about 22° in the case of the material used by Nito et al. (cf. p. 165, fig. 6) and thus produces a maximum transmission of only 50% of the transmission of two parallel polarizers.

Terada et al. have suggested a monostable FLC configuration (Terada, M., Togano, T., Asao, Y., Moriyama, T., Nakamura, S., Iba, J., presented at the Applied Physics 10 Conference, March 28, 1999, Tokyo, Japan; Abstract No. 28p-V-8). With respect to the phases, Terada et al define the sequence I-N-C as "sufficient". However, these prototypes are not yet suitable for practical use over a relatively large temperature range. One reason for this is that, in practice, I-N-C is a necessary, but not a sufficient condition, and suitability for practical use places a number of additional 15 conditions on the liquid crystal.

It is an object of the present invention to provide a suitable chiral smectic liquid-crystal mixture and a switching and display device comprising such a suitable chiral smectic liquid-crystal mixture, where the liquid-crystal mixture makes it possible, 20 owing to its excellent alignment properties and specified favorable alignment angles, to achieve a very high contrast over a broad temperature range.

A precondition for a very high contrast over a broad temperature range is an extremely small dark transmission of the LCD cell. This is in turn achieved, on the 25 one hand, only when the mixture has excellent alignment properties, because any defect or local deviation of the director from the dark position reduces the contrast significantly, and, on the other hand, when the alignment varies only slightly with temperature. This applies in particular when considering a broad operating temperature range, e.g. from -10°C to +60°C, preferably from 0°C to +55°C, in 30 particular from 10°C to 50°C.

This object is achieved according to the invention by a liquid-crystal switching or display device comprising a chiral smectic liquid-crystal mixture, characterized in that the ratio  $\Delta/\Theta$  of the angle between the rubbing direction and the smectic layer normal to the tilt angle in the liquid-crystal mixture is at least 0.41.

5 Preferably, the object is achieved by a chiral smectic switching or display device which utilizes a chiral smectic liquid-crystal mixture having the phase sequence I-N-C, the symbols having the following meaning:

10 I = isotropic phase

N = nematic or cholesteric phase

C = smectic C phase (including all sub-types of the C phase) or another tilted phase, chiral or containing chiral dopants (the symbol \* which is customary in the literature is omitted for the sake of simplicity of representation), and the alignment being such

15 that the angle ratio w, defined as

$$w = \Delta/\Theta \text{ is at least 0.41, where}$$

20  $\Delta$  is the angle between the rubbing direction (Fig. 1, axis 1) and the smectic layer normal (Fig. 1, axis 2), where the term rubbing direction includes a preferential direction obtained by other processes than a rubbing treatment, e.g. photo-alignment or the like, and  $\Theta$  is the tilt angle, preferably determined by the response behavior by means of electric voltages or X-ray analysis (Fig. 1, axes 2 and 4' or 2 and 4, respectively).

25

Preference is given to w values of at least 0.45, particularly preferably > 0.53, in particular between 0.55 and 0.99, most particularly between 0.60 and 0.85.

30 Particularly preferably, w is at least 0.41 while simultaneously limiting the tilt angle range to 19° to 39°, preferably 20° to 36°, particularly preferably 22° to 34°, most preferably 23° to 33°, in particular 24° to 32° (at 25 °C).

Moreover, the object is achieved according to the invention by a chiral smectic liquid-crystal switching or display device comprising a chiral smectic liquid-crystal mixture having the phase sequence I-N-C in monostable alignment, the alignment 5 being such that the angle  $\rho$  between the rubbing direction and the monostable position (maximum dark position, axes 1 and 3 in Fig. 1) is at least  $1^\circ$ , preferably at least  $1.3^\circ$ , particularly preferably at least  $1.6^\circ$ , in particular at least  $1.9^\circ$ .

Preference is given to combinations of the features of the first and second, first and 10 third, second and third, or first, second and third above-described embodiments of the liquid-crystal switching and display device of the invention.

Particularly preferably,  $w$  is at least 0.41 while simultaneously having an angle  $\rho$  of more than  $1^\circ$ .

15 Particularly preferably,  $w$  is at least 0.41 while simultaneously limiting the tilt angle range to  $19^\circ$  to  $39^\circ$  (at  $25^\circ\text{C}$ ) and, as additional condition, having an angle  $\rho$  of more than  $1^\circ$ .

20 Particularly preferably,  $w$  is at least 0.41 while simultaneously limiting the tilt angle range to  $19^\circ$  to  $39^\circ$  (at  $25^\circ\text{C}$ ), having an angle  $\rho$  of more than  $1^\circ$  and, as additional condition, having a spontaneous polarization of  $< 150 \text{ nC/cm}^2$ .

Preference is given to a mixture having the phase sequence I-N-C whose 25 spontaneous polarization in the operating temperature range is  $< 150 \text{ nC/cm}^2$ , particularly preferably  $< 70 \text{ nC/cm}^2$ , very particularly preferably  $< 35 \text{ nC/cm}^2$ , in particular  $< 15 \text{ nC/cm}^2$ , most particularly in the range from 4.1 to  $9.9 \text{ nC/cm}^2$ .

Such displays exhibit a virtually or completely defect-free alignment and a dark 30 position which is very dark, and thus have a high contrast over a broad temperature

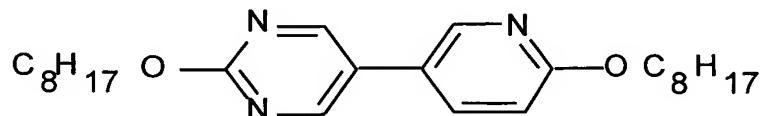
range. Examples of such displays are active-matrix displays or passive-matrix displays.

5 The object is likewise achieved according to the invention by a chiral smectic switching or display device, in particular by an active-matrix display containing a liquid-crystal mixture and by the liquid-crystal mixture itself which have the phase (transition) sequence



10 having a moderately, i.e. not too weakly and not too strongly, suppressed smectic A phase which manifests itself by one or both of the following features:

- increasing the concentration of at least one component of the mixture which induces a smectic A phase by 25% by weight, based on the total mixture, leads to 15 the occurrence of a significant smA phase range in the mixture, whereas increasing the concentration by only 5% by weight does not lead to the occurrence of an smA phase, or
- the addition of ten (10) % by weight, based on the total mixture, of a smectic A inducer, preferably component A, CAS registration no. 156682-16-5, 20 designation: 5-[6-(octyloxy)-3-pyridinyl]-2-(octyloxy) pyrimidine



25

leads to the occurrence of an smA phase range of less than 5.5°C (phase width), but of at least 0.1°C on addition of 25% by weight, bases on the total mixture, of component A.

30 The invention furthermore relates to a process for finding suitable liquid-crystal mixtures which comprises the abovementioned process steps.

Furthermore, the LCD cell is advantageously asymmetrical, i.e. the top surface and the bottom surface of the cell differ in at least one feature apart from a possible active-matrix construction (thin-film transistor) itself. This is in particular the case:

- 5     • when using unsymmetrical or unsymmetrically treated alignment layers (for example in the case of antiparallel rubbing)
- when one of the two alignment layers is omitted
- when the step of rubbing one of the two alignment layers is omitted or changed
- 10    • when an unsymmetrical layer structure is introduced, for example by additional insulation layers having different properties on their top and bottom surfaces
- with all measures which finally result in exposure of the liquid-crystal domain to an unsymmetrical environment in relation to a symmetry plane parallel to the electrode surfaces.
- 15

Expressly included is the advantageous use of the novel materials and mixtures for active-matrix displays, antiferroelectric displays and smectic displays, the term “display” being intended to mean any type of optical display or switching device 20 regardless of its size, structure, light guidance, addressing and use.

In particular, the term “active-matrix display” as used herein includes an LCD in which one of the two substrates is replaced by the rear side of an IC chip (IC = integrated circuit) as described, for example, in D.M. Walba, Science 270, 250-251 25 (1995) or <http://www.displaytech.com>, i.e. the LCOS (LC On Silicon) technology.

In particular, the term "active-matrix display" as used herein includes an LCD in which one of the two substrates is replaced by the rear side of a plasma cell (plasma-addressed LCD).

- 5 In general, preference is given to displays having an electrode separation of 0.7 to 3.0  $\mu\text{m}$ , in particular active-matrix displays having an electrode separation of 0.8 to 2.0  $\mu\text{m}$ , which contain a chiral smectic mixture exhibiting a weakly suppressed smA phase.
- 10 Particular preference is given to a display utilizing pulsed or rapidly changing backlight ("sequential backlight" technology).

The object is likewise achieved by the use of a chiral smectic liquid-crystal mixture having the phase sequence I-N-C as electro-optically active layer in monostable 15 switching and display devices or displays, characterized in that the chiral smectic liquid-crystal mixture has the following combination of properties:

TC greater than 50  $^{\circ}\text{C}$  and  
T<sub>NI</sub> less than 105  $^{\circ}\text{C}$  and  
19 $^{\circ}$  < tilt angle (25 $^{\circ}\text{C}$ ) < 39 $^{\circ}$  and  
20 spontaneous polarization less than 150 nC/cm<sup>2</sup> and  
pitch of the cholesteric helix greater than 2  $\mu\text{m}$  and

the difference of the tilt angles measured at 15 $^{\circ}\text{C}$  and 5 $^{\circ}\text{C}$  below T<sub>c</sub>, the upper limit 25 of the range of existence of the optically active smectic phase, is less than 9.5 $^{\circ}$ . It is advantageous that the (total) content of N- and/or S-heterocyclic compounds in the mixture is at least 20% by weight. Particular preference is given to thiophene derivatives.

In the drawing:

5 Fig. 1 is a schematic representation of the position of the respective angles used relative to one another

Fig. 2 is the phase diagram for Example 1

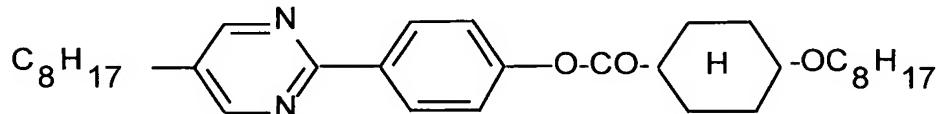
Fig. 3 is the optical transmission of a test cell as a function of the voltage for a mixture from Example 6.

10 10 The invention is explained in greater detail by the examples below.

Example 1

To illustrate the moderately suppressed smA phase, a mixture is prepared from a mixture M1 and component B:

15



20 The concentration of component B is continuously varied. In this way, a two-dimensional portion of the phase diagram of the mixture is obtained which is depicted in Fig. 2.

Table 1: Composition of test mixture M1:

<chem>C8H17-O-c1ccnc2cc(OR)cc2c1</chem>	% by weight
R = C <sub>8</sub> H <sub>17</sub>	14.43
R = C <sub>6</sub> H <sub>13</sub>	29.12
R = C <sub>4</sub> H <sub>9</sub>	28.47
R = C <sub>10</sub> H <sub>21</sub>	27.98
total % by weight	100.00

The NAC tricritical point occurs at ([M1]=66% by weight, [B]=34% by weight) as depicted in Fig.2 (in Fig.2, T denotes the temperature in degrees Celsius, [B] the weight percentage of component B, based on the total mixture). I, N, C have been 5 defined above. A denotes smectic-A phase. The vicinity of the NAC point according to the invention is determined as follows.

Six test mixtures having the following compositions are prepared:

Table 2: Test mixtures P-U and phase sequences thereof

10

Mixture	[M1]	[B]	Phase sequence
	% by weight		Phases, temperature in °C
P	75	25	C 85.3 A 90,6 N 108 I
Q	66	34	C 85.6 (NAC) 85.6 N 115 I
R	60	40	C 85.6 N 116 I
S	55	45	C 86,5 N 119 I
T	50	50	C 87 N 122 I
U	20	80	C 92.7 N 145 I

The resulting mixtures are admixed with 10% by weight of component A (as defined above) as smA inducer. The following phase ranges are obtained:

15 Table 3: Test mixtures PA-UA and phase sequences thereof following addition of component A (see above, 10% by weight)

Mixture	90 wt%	Phase sequence with 10 wt% of A	Width of smA-phase
		Phases, temperature in °C	°C
PA	P	C 82.6 A 94.3 N 103 I	11.7
QA	Q	C 85.5 A 93.0 N 106 I	7.5
RA	R	C 86.8 A 92.5 N 109 I	5.7
SA	S	C 88.2 A 90.6 N 112 I	2.4
TA	T	C 88.5 (NAC) 88.5 N 114 I	0.0
UA	U	No smA phase	0.0

These data show that the mixtures U,T,S are within the preferred range of the present invention as they are far enough away from the NAC multicritical point and the smA phase is sufficiently strongly suppressed. In particular, smA phase ranges of more than 0.1°C occur in the mixtures T, S and U upon addition of 25% of component A.

5

The spontaneous polarization can be adjusted to virtually any value by addition of a suitable chiral substance or substance mixture. For example, the addition of 5% by weight of component C8 (see Example 3 below) to mixture T gives a chiral smectic mixture having the phase sequence

10 I 115 N 84 C.

having  $P_s = -7,8 \text{ nC/cm}^2$  and a tilt angle of 27° at 25°C.

#### Example 2 LCD test cell

An LCD test cell is prepared from two commercially available glass plates which are 15 transparently and conductively coated with indium-tin oxide. The plates are spin-coated (2500 rpm, 10 s) with the alignment layer LQT-120 (from Hitachi Chemicals KK) which was diluted to 8.3% of its original solids content using N-methylpyrrolidone, cured by heating (230°C, 1 h) and then aligned by subjecting them to a rubbing process (rubbing material: rayon type YA-20-R\*, clearance 20 0.2 mm, once, roller speed 700 rpm, substrate speed 10 cm/s, roller diameter 10 cm).

The rubbed glass plates are arranged such that the rubbing direction is antiparallel, adhesively bonded to produce test cells and set 1.3 μm apart by means of a spacer.

25 The FLC mixture is introduced into the cell and initially aligned in the nematic or cholesteric phase by cooling. On further cooling, a 3 Volt direct voltage is applied and the cell is transferred into the smC phase (chiral smectic C) range at a cooling rate of 2 K/min. During this process, a monstable domain is formed when mixtures according to the invention are used.

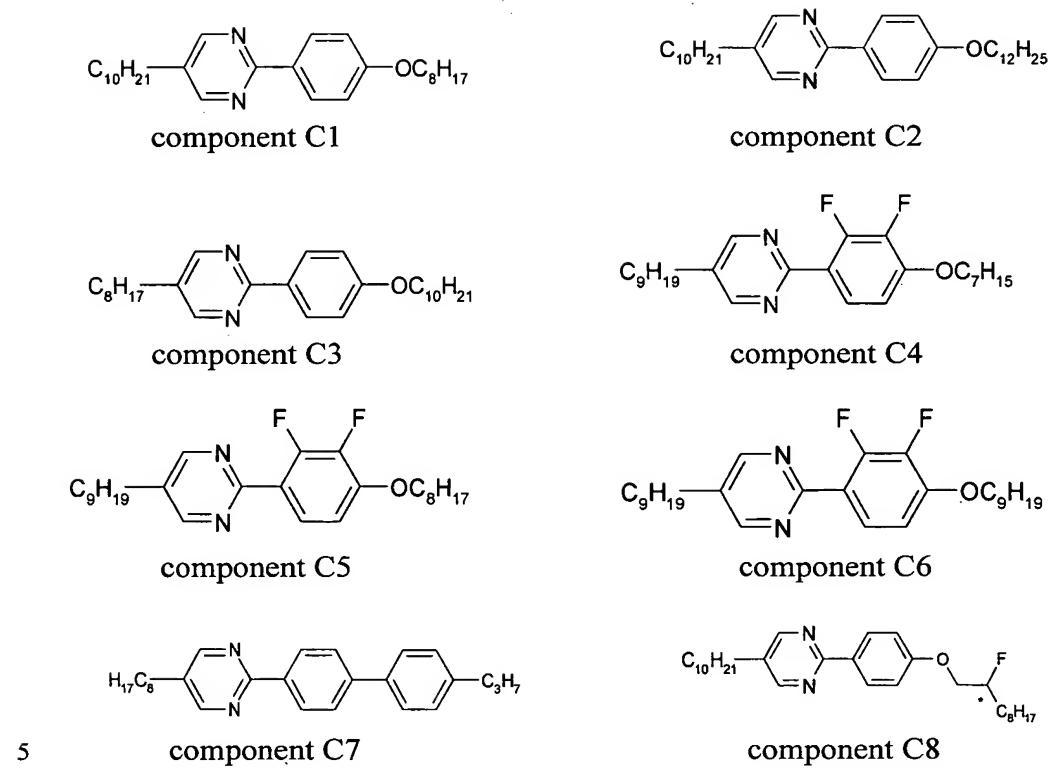
30

The rubbing direction, if it is not known anyway, can be determined experimentally by transfer into the nematic phase by heating and subsequent determination of the dark position between crossed polarizers.

5 The tilt angle can be determined experimentally by switching the cell at operating temperature. Here, a saturation of the optical transmissions at positive and negative voltage (typically 20 V) is observed which are associated with specific angles of rotation (Fig. 1, axes 4, 4'). The angle difference at saturation gives the value  $2\Theta$  (=twice the tilt angle), the angle bisector gives the layer normal (Fig. 1, axis 2). The  
10 dark position can be determined easily.

### Example 3

Test mixtures are prepared from the following components C1-C8 (mixtures V,W,X,  
15 see Table 4). The phase transitions and some properties of the cell described in Example 2 and produced using these mixtures are summarized in Table 5.



5

**Table 4:** Compositions of mixtures V,W,X

Component	V	W	X
C1	14.4%	7.2%	
C2	14.4%	7.2%	
C3	14.4%	7.2%	
C4	14.4%	21.6%	28.8%
C5	14.4%	21.6%	28.8%
C6	14.4%	21.6%	28.8%
C7	10.0%	10.0%	10.0%
C8	3.6%	3.6%	3.6%

10

**Table 5:** Properties of the chiral smectic mixtures and of the cell produced by the method described in Example 2

Mixture	Tc	$\Delta Sa$	Ps (nC/cm <sup>2</sup> ) 25°C	10V, 60Hz		$\Sigma$	$\Sigma/\Theta$	$\Delta$	W= $\Delta/\Theta$
				$\Theta_{Tc-10}$	$\rho$				
V	62.8	1.5	3.7	19.9	-	19.9	1.0	0	0
W	56.1	0	4.8	23.1	3.6	13.7	0.59	9.4	0.41
X	59.2	0	5.9	23.9	4	12.2	0.51	11.7	0.49

5 The mixtures W and X have the phase sequence I-N-C and a  $\Delta/\Theta$  ratio of 0.41 (V) and 0.49 (W). In contrast, the use of mixture V having the phase sequence I-N-A-C does not result in advantageous utility for the purposes of the present invention.

#### Example 4

10 The mixtures W, X are admixed with component A, again such that the concentration of component A in these new mixtures is 10 percent by weight. The following smA phase widths ( $\Delta Sa$ ) are obtained:

15 Table 6: smA phase range with 10% by weight of component A in °C

Mixture	Tc	$\Delta Sa$
W	59	4
X	62	2.5

20 These date show that the mixtures W and X have a sufficiently strongly suppressed smA phase which appears on addition of 10% of the smA inducer, and a width of less than 5.5°C. On addition of 25% by weight of component A, SmA phase ranges of more than 0,1°C are obtained.

### Example 5

5 The response properties of the test cells filled with the mixtures W and X (Table 2) are examined. To this end, the optical transmission between crossed polarizers is examined as a function of the applied voltage (bipolar pulse sequences having a frequency of 60 Hz = width of 8.3 ms). The following results were obtained at a temperature of 30°C:

10 Table 7: Analog gray scale using mixtures W and X

Voltage (Volt)	Transmission (%)	Transmission (%)
	Mixture W	Mixture X
0	0	0
0.5	2	14.8
1	5.4	24.2
1.5	12	40.2
2	21.4	48.4
2.5	38.2	53.8
3	48.4	57.6
3.5	54	60.4
4	59.6	63.2
4.5	63.2	65
5	65.8	66.6
8	71.2	69.6
10	72.2	70

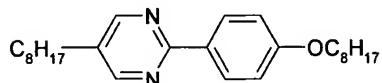
Response times (10 V) of mixture W: 0.22 ms (0-50%) or 0.15 ms (100-50%)

Response times (10 V) of mixture X: 0.20 ms (0-50%) or 0.12 ms (100-50%)

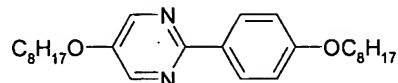
Both mixtures having a moderately, but sufficiently strongly suppressed smA phase can be utilized advantageously because an analog gray scale and submillisecond response at low values of spontaneous polarization are realized.

### 5 Example 6

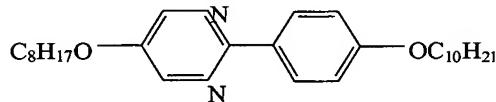
Another eight test mixtures are prepared which contain the following components:



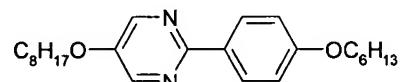
component C9



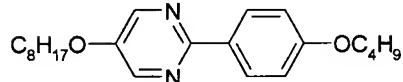
component C10



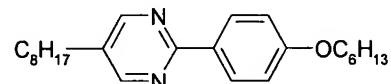
10 component C11



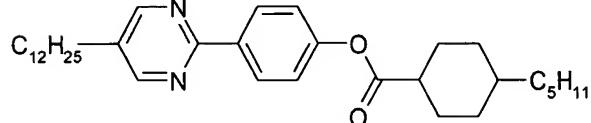
component C12



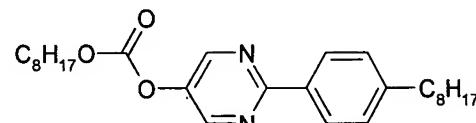
component C13



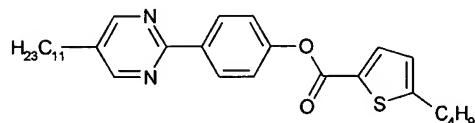
component C14



component C15



component C16



component C17

**Table 8:** Compositions of the test mixtures Y1 to Y8. Amounts are given in percent by weight.

Component	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8
C9	8.5%	9.7%	10.8%	12.0%	13.0%	9.6%	8.5%	7.4%
C10	2.8%	3.2%	3.6%	4.0%	4.4%	3.2%	2.8%	2.5%
C3	6.8%	7.7%	8.6%	9.5%	10.4%	7.7%	6.8%	5.9%
C12	5.7%	6.5%	7.3%	8.1%	8.8%	6.5%	5.7%	5.0%
C13	5.6%	6.4%	7.1%	7.9%	8.6%	6.4%	5.6%	4.9%
C11	5.5%	6.3%	7.0%	7.8%	8.5%	6.3%	5.5%	4.8%
C14	8.8%	10.0%	11.1%	12.4%	13.5%	10.0%	8.8%	7.7%
C15	12.3%	14.0%	15.6%	17.3%	18.9%	13.9%	12.3%	10.7%
C16	10.0%	10.0%	10.0%	10.0%	10.0%	9.0%	7.9%	6.9%
C4	10.0%	7.5%	5.0%	2.5%	0.0%	4.5%	4.0%	3.4%
C6	10.0%	7.5%	5.0%	2.5%	0.0%	4.5%	4.0%	3.4%
C5	10.0%	7.5%	5.0%	2.5%	0.0%	4.5%	4.0%	3.4%
C17	0.0%	0.0%	0.0%	0.0%	0.0%	10.0%	20.0%	30.0%
C8	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%

5 The mixtures Y1 to Y8 were now examined for their response properties, quality of alignment, temperature dependence of contrast and tilt angle, the angles as represented in Fig. 1, the angle ratio  $w$  and the extent of smectic A phase suppression. The experimental results are summarized in Table 9. In the table, the quantities  $TC$  (temperature dependence of contrast) and alignment were categorized 10 by visual inspection and optical measurements into three classes (+ good, 0 medium, - bad). The quantity  $TT$  is determined from measurements of the temperature dependence of the tilt angle at  $5^\circ\text{C}$  ( $\Theta_5$ ) and  $15^\circ\text{C}$  ( $\Theta_{15}$ ) below  $T_c$ , the limit of the range of existence of smC. Then:

15 
$$TT = (\Theta_{15} - \Theta_5)/10.$$

The quantities  $Vo$  and  $Vs$  are defined in Fig. 3 (threshold voltage and saturation voltage, respectively). Fig. 3 depicts the optical transmission of a test cell as a function of the voltage for the mixture Y7 which is very suitable.

**Table 9:** Measured data for the test mixtures Y1 to Y8

Measured quantity [Unit]	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8
T <sub>NI</sub> [°C]	76	79	83	85	86	82	84	84
T <sub>NA</sub> [°C]					68.8			
T <sub>c</sub> [°C]	62.8	64.6	66.1	67.0	67.5	63.6	60.7	59.1
Δ smA [°C]	0	0	0	0	1.3	0	0	0
Θ [°] 20 V, T <sub>c</sub> -30°C	29.5	28.3	27.6	26.0	23.7	28.2	29.0	29.6
Δ [°]	20.4	18.5	14.7	10.6	0	18.7	22.4	23.6
ρ [°]	3.4	3.5	3.3	3.5		3.0	2.2	3.0
Σ [°]	9.1	9.8	12.9	15.4	23.7	9.5	6.6	6
w = Δ / Θ	0.692	0.654	0.533	0.408	0.000	0.663	0.772	0.797
Σ / Θ	0.308	0.346	0.467	0.592	1.000	0.337	0.228	0.203
ρ / Σ	0.374	0.357	0.256	0.227		0.316	0.333	0.500
Δ smA* [°C] +10% comp. A	3.2	3.3	5.4	5.7	7.9	0.8	0.0	0.0
V <sub>o</sub> [Volts]	0.8	0.7	0.3	1.0	-	0.8	1.0	0.3
V <sub>s</sub> [Volts]	6	6	7	6	-	8	4.5	3.8
Alignment	+	+	0	0	-	+	+	+
T <sub>C</sub> (cf. text)	0	0	-	-	-	+	+	+
T <sub>T</sub> (cf. text)	0.61	0.62	0.72	0.95	0.75	0.49	0.38	0.29
Overall evaluation of the cell	+	+	0	-	-	+	+	+

**Patent Claims**

1. A liquid-crystal switching or display device comprising a chiral smectic liquid-crystal mixture, characterized in that the ratio  $\Delta/\Theta$  of the angle between the rubbing direction and the smectic layer normal to the tilt angle in the liquid-crystal mixture is at least 0.41.  
5
2. A liquid-crystal switching or display device as claimed in claim 1, characterized in that the liquid-crystal mixture has the phase sequence I-N-C and the tilt angle  $\Theta$  at 25°C is between 19° and 39°.  
10
3. A liquid-crystal switching or display device comprising a chiral smectic liquid-crystal mixture having the phase sequence I-N-C in monostable alignment, characterized in that the angle  $\rho$  between the rubbing direction and the monostable position is at least 1°.  
15
4. A liquid-crystal switching or display device comprising a chiral smectic liquid-crystal mixture having the phase sequence I-N-C in monostable alignment, characterized in that the difference of the tilt angles measured at 15°C and 5°C below  $T_c$ , the upper limit of the range of existence of the optically active smectic phase, is less than 9.5°.  
20
5. A liquid-crystal switching or display device as claimed in one of claims 1 to 4, characterized in that the mixture has a spontaneous polarization of less than 150 nC/cm<sup>2</sup>.  
25

6. A liquid-crystal switching or display device as claimed in one of claims 1 to 4, characterized in that the device is an active-matrix or passive-matrix display.
- 5 7. The use of a chiral smectic liquid-crystal mixture having the phase sequence I-N-C as electro-optically active layer in monostable switching and display devices or displays, characterized in that the chiral smectic liquid-crystal mixture has the following properties:

$T_C$  greater than  $50^\circ\text{C}$  and  
10  $T_{NI}$  less than  $105^\circ\text{C}$  and  
 $19^\circ < \text{tilt angle } (25^\circ\text{C}) < 39^\circ$  and  
spontaneous polarization less than  $150 \text{ nC/cm}^2$  and  
pitch of the cholesteric helix greater than  $2 \mu\text{m}$  and  
the difference of the tilt angles measured at  $15^\circ\text{C}$  and  $5^\circ\text{C}$  below  $T_C$ , the  
15 upper limit of the range of existence of the optically active smectic phase, is  
less than  $9.5^\circ$ .
8. The use as claimed in claim 7, characterized in that the switching and display device is as defined in one of claims 1 to 6.
- 20 9. The use as claimed in claim 8, characterized in that the total content of nitrogen- or sulfur-containing heterocyclic compounds in the mixture is at least 20% by weight.
- 25 10. The use as claimed in claim 9, characterized in that the mixture contains at least one thiophene derivative.

11. A chiral smectic liquid-crystal mixture having the phase sequence I-N-C, characterized in that the addition of 10% by weight, based on the total mixture, of a smectic A inducer leads to the occurrence of an smA phase range of less than 5.5°C, and the addition of 25% by weight, based on the total mixture, leads to the occurrence of an smA phase range of at least 0.1°C.

**Abstract**

The liquid-crystal switching or display device comprises a chiral smectic liquid-crystal mixture, where the ratio  $\Delta/\Theta$  of the angle between the rubbing direction and the smectic layer normal to the tilt angle in the liquid-crystal mixture is at least 0.41. 5 Preferably, the liquid-crystal mixture has the phase sequence I-N-C and the tilt angle  $\Theta$  at 25°C is between 19° and 39°.



1/3

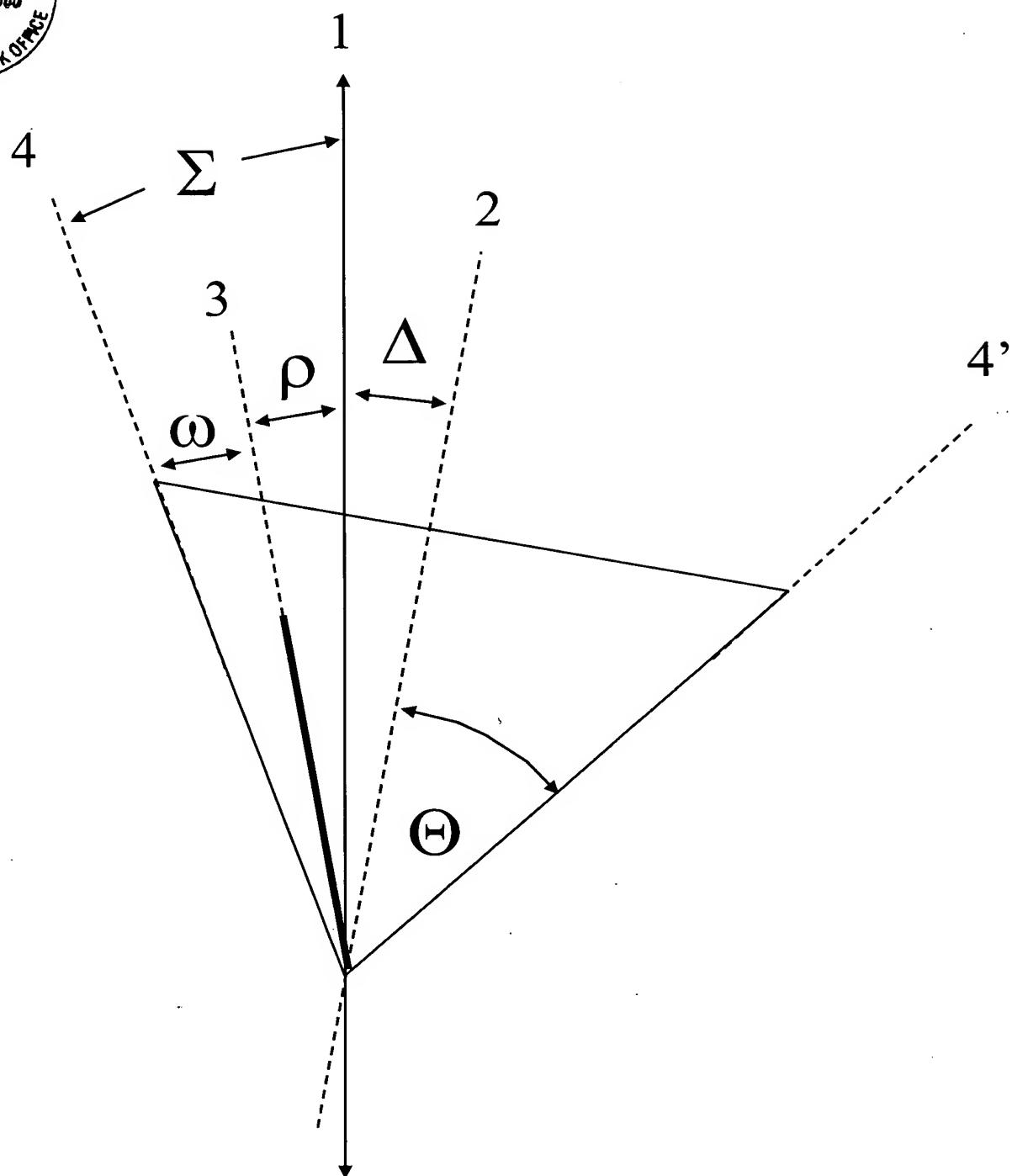
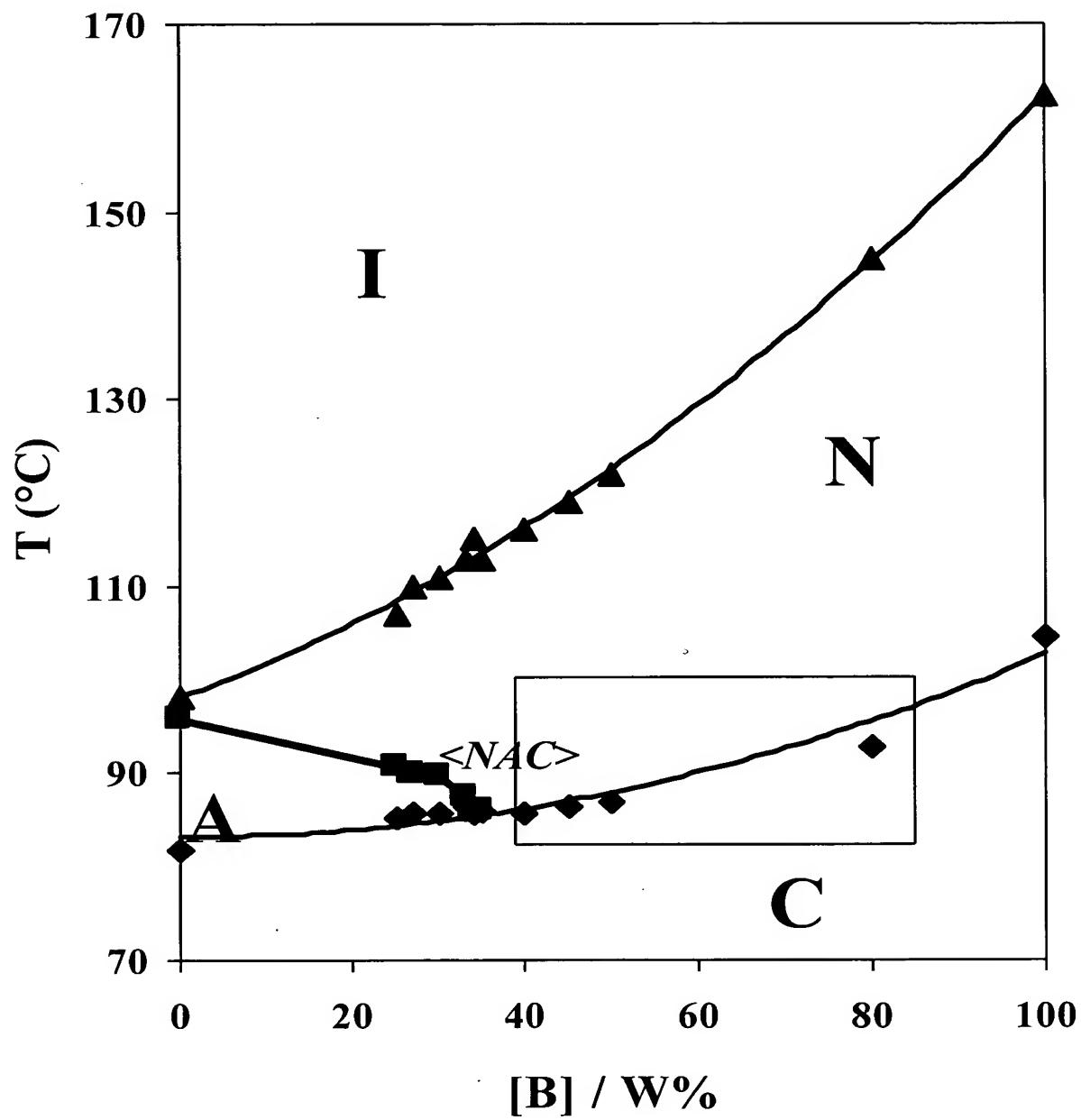
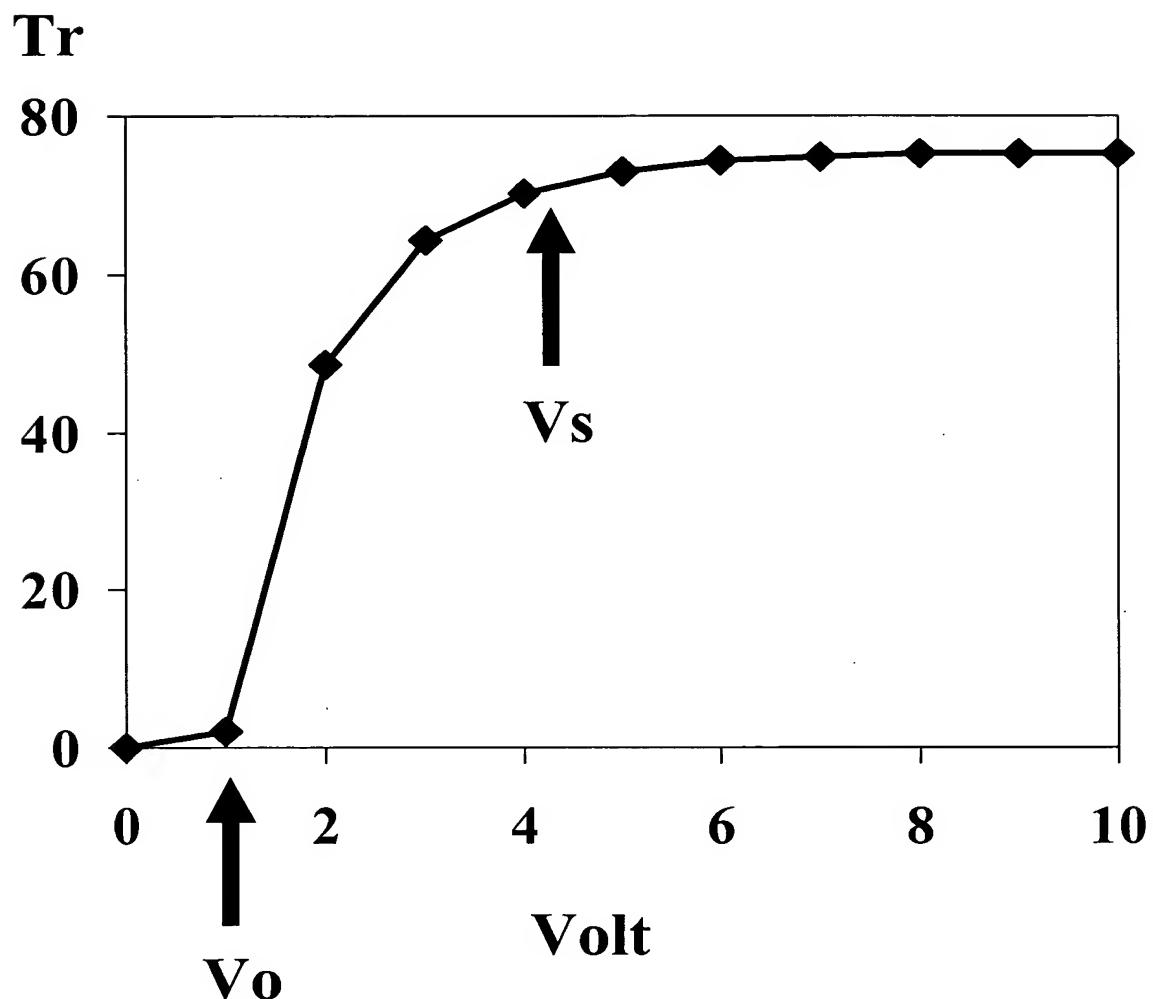


Fig. 1



**Fig. 2**



**Fig. 3**